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STUDY ON BEHAVIOUR OF SELF HEALING CONCRETE, A REVIEW

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ABSTRACT

This paper examines the behaviour of self-healing concrete. By collecting, categorising, and analysing concrete self-healing references from both domestic and international sources. Self-healing concrete includes concrete-based self-healing concrete, shape memory alloy-based self-healing concrete, bionic self-repairing concrete, and microbial-based self-healing concrete.

Water and other pollutants can enter the concrete through cracks, diminishing its durability and strength. When it comes into contact with water, CO2, or other chemicals, it has an effect on the reinforcement. To mend the cracks that have developed in the concrete, regular care and a special type of treatment that is very expansive are required. To address this problem, concrete has been designed with a self-healing mechanism that aids in the mending of cracks by generating calcium carbonate crystals that patch micro fissures and pores. The bacteria were chosen for their ability to thrive in alkaline conditions. Distinct bacteria species have different growing conditions. Bacteria were cultivated at a specified temperature and for a specific time period in a medium containing various substances. Bactria improves the structural properties of normal concrete, such as tensile strength, water permeability, durability, and compressive strength, as discovered through various types of experiments on a large number of specimens of varying sizes used by various researchers for their study of bacterial concrete vs. conventional concrete. The investigation also revealed that employing light weight aggregate in conjunction with microorganisms helps with self-compaction. In order to attain the best result, a mathematical model was created to evaluate the stress-strain behaviour of bacteria, which was then used to improve the strength of concrete.

The ability of self-healing concrete to repair tiny cracks on its own is the most popular definition. The concept of self-healing concrete was inspired by the animals. Skin that has been damaged on trees and animals can be repaired on their own. Cracks in concrete structures must be repaired to preserve their long-term serviceability and structural safety.

KEYWORDS: Self-Healing, Self-Repair, Autonomous Healing, Automatic Healing, Auto-Treatment, Self-Treatment, Bio- Concrete, Bio-Inspired, Biological Concrete, Calcite, Bio- Mineralization & Calcite Precipitation

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Original Article

1. INTRODUCTION

A concrete structure is the most essential civil engineering structure. Engineers and technical professionals have continued to undertake research since the structure's start, and concrete materials have been manufactured in the direction of high strength, high performance, and versatility, as the structure's complexity and size have grown. Concrete, on the other hand, is a fragile, low-tensile-strength material. Cracks in the structure may arise during construction or use due to the nature of the material, the construction process, environmental conditions, and load

impacts, and even cracks that are visible to the naked eye may occur. A variety of techniques can be used to repair cracked concrete structures. Today, epoxy resin reinforcement grouting is a widely used technique. It has high mechanical strength, heat resistance, and stability, as well as a high bonding force and minimal shrinkage after curing. These techniques, on the other hand, are typically utilised to mend big cracks and have limited autonomy. It's difficult to repair very small cracks or micro cracks inside a structure. As modern science and technology advanced, people became increasingly interested in the novel technique of concrete self-healing to repair cracks in this environment. As a method of processing and regulating cracks, self-healing concrete research has exploded in popularity. A fissure in the concrete can self-heal without the need for human intervention once it occurs. Then there's self-healing concrete, which is a crack-repair method.

Engineers and scientists are looking for ways to make structures that are more robust and less expensive to repair. Society has squandered large sums of money due to the poor quality and durability of concrete and road structures, as well as their environmental impact. In Europe, it is estimated that 50% of the annual construction budget is spent on restoring and rehabilitating old structures.

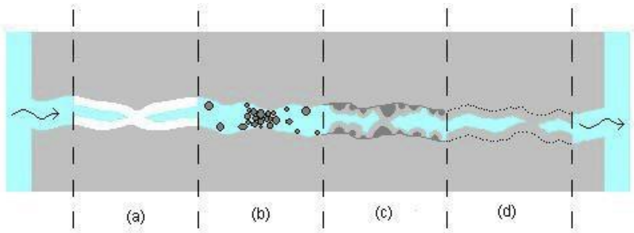

Figure 1: The Formation of Calcium Carbonate or Calcium Hydroxide, Particle Sedimentation, Continual Hydration, or Cement-Matrix Expansion can all Contribute to Self-Healing (TerHeide 2005).

The bacteria have been chosen for their ability to thrive in an alkaline environment. Most bacteria die in an alkaline environment with a pH of 10 or higher, which creates spores that look like plant seeds. The spores have a thick wall and are activated when the concrete cracks and water leaks into the structure.

Table 1: Bacteria other then Bacillus which are Survive in the Alkaline Environment

S. No	Application	Types of Bacteria
1	As a crack healer	Bacteria. pasteurii
		Deleya Halophila
		Halomona srurihalina
		Myxococcus Xanthus
		Bacteria megaterium
2	For surface treatment	Bacteria sphaericus
		Bacilllus subitilis
3	Bacteria spharicus	Bacteria sphaericus
		Thiobacillus

Jonker et al. [5] utilised Bacilluscohnii bacteria to precipitate CaCo3, while other researchers employed different types of bacteria to examine microorganisms. 1 mol urea is first degraded intracellularly to 1 mol ammonia (Eq. (1)). Carbonate hydrolyzes spontaneously to produce 1 mol of ammonia and 1 mol of carbonic acid (Eq. (2)). These products then combine to generate 1 mol bicarbonate, 2 mol ammonium, and 4 mol hydroxide ions (Eqs. (3) and (4)). The last two reactions result in an increase in pH, which alters the bicarbonate equilibrium, causing carbonate ions to form (Eq. (5)). [9]

$CO(NH_2)_2 + H_2O\ NH_2COOH + NH_3$ (1)

$NH_2COOH + H_2O\ NH_3 + H_2CO_3$ (2)

$H_2CO_3\ HCO_3^- + H^-$ (3)

$2NH_3 + 2H_2O\ 2NH_4^- + 2OH^-$ (4)

$HCO_3^- + H^+ + 2NH_4^+ + 2OH^-\ CO_3^{2-} + 2NH_4^+ + 2H_2O$ (5) Since the cell wall of the bacteria is negatively charged, the bacteria draw cations from the environment, including Ca^{2+}, to deposit on their cell surface. The Ca^{2+}-ions subsequently react with the CO_3^{2-}-ions, leading to the precipitation of $CaCO_3$ at the cell surface that serves as a nucleation site (Eqs. (6) and Eqs. (7).

Ca^{2+} + Cell Cell-Ca^{2+} (6)

Cell-Ca^{2+} + CO_3^{2-} Cell-$CaCO_3$↓ (7)

2. MATERIAL AND METHODS OF SELF- HEALING PROJECTS

2.1 Detailing of Bio Concrete

In this work, the ability of microorganisms to act as a self-healing agent in concrete is investigated. Although the concept of embedding bacteria into a concrete matrix may appear unusual at first, it is not in terms of microbiology. Bacteria can be found practically anywhere on the earth, not just on the surface, but also deep within, such as in silt and rock at depths of over one kilometre. Various types of extremophilic bacteria, or bacteria that flourish in extreme habitats, have been found in extremely dried locations such as deserts, inside rocks, and even ultra-basic environments such to the internal concrete environment. Many desiccation- and/or alkali-resistant bacterial species have the ability to produce endospores. These specialised cells, which have a low metabolic activity, have been found to tolerate high mechanical and chemical pressures and live for up to 200 years. Previous studies have described the use of bacteria for cleaning concrete surfaces (De Muynck 2008) and enhancing the strength of cement-sand mortar (Bang et al 2001). Although positive results were obtained, the fundamental restriction of the latter experiments was that the bacteria and chemicals required for mineral precipitation could only be applied to the structure's surface after the fracture had formed. This methodological necessity was forced by the short life-time (hours to a few days) of the (urease-based) enzymatic activity and/or viability of the used bacterial species. This study investigates the employment of alkali-resistant endospore-forming bacteria to increase concrete's self-healing capacity, and the tensile and compressive strength characteristics of reference (no bacteria added) and bacterial concrete are measured (Jonkers and Schlangen 2007). In addition, the feasibility of bacteria immobilisation in concrete is determined, and an ESEM analysis is utilised to show the calcite precipitation potential of bacterial concrete. As an example, Figure 2 shows calcite crystals formed by bacterial precipitation.

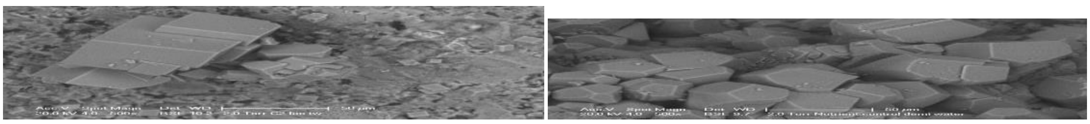

Figure 2: Biominerals Observed by ESEM.

As a result, a new approach was devised that contained a biochemical healing agent composed of bacterial spores as well as an organic bio-cement precursor ingredient. Both spores and food are immobilised in reservoir porous expanding clay particles. As a result, spores and bacteria are protected while the concrete is being made and hardened, allowing them to survive longer until self-healing is necessary.

Figure 3. Cracked concrete specimens with porous aggregates, food-only (A) (top) and food-plus-bacteria (B) (bottom). The situation before healing is depicted on the left, while the situation after healing is depicted on the right.

Porous aggregates loaded with either food (lactate) or both food and bacteria are used to make concrete discs. The specimens are cured for 56 days before being cracked partially in a tensile splitting force regulated by deformation. The specimens are then placed in a permeability test setup, which entails soaking one side of the specimen in water for 24 hours. After the cracks have healed, they are examined under a microscope, and the results are shown in figure 3.

2.1. Cracks Size in Concrete

According to the study and inquiry of different authors, the cracks healed by autogenously healing were found in varied diameters ranging from 0.05mm to 0.87mm, 5.0mm to 10m, 100m and more.

2.2. The Effect of the pH on the Growth of the Bacteria

Bacterial growth is influenced by pH as well. Each microbial species has a different pH range. Nutrients with pH levels ranging from 4 to 12 were generated in a test tube. The test was carried out by utilising a photo calorimeter to measure the turbidity of the sample, and it was discovered that the growth was in the PH range of 7.5-9.0. Bacillus pasteurii thrived in a PH range of 7.0-9.0, while Bacillus spherics thrived in a PH range of 8.0-9.0. 3. Collection of concrete samples

2.3. Sampling of Concrete

Willem De Muynck et al. made a concrete specimen out of ordinary Portland cement CEM 152.5 N, sand, aggregate, and water to analyse and test the self-healing characteristics of concrete. 150 mm X 150 mm X 150 mm, 150 mm X 150 mm X 600 mm, and 160 mm X 160 mm X 70 mm were the moulds used. At a temperature of 20 to 25 degrees Celsius, the specimens were kept in the chamber for 27 days. After 28 days, a compression test was performed on the produced cube, which yielded a mean compressive strength of 55.2 N/mm2 with a standard variation of 2.19 N/mm2.

2.4. Light Weight Aggregate

LWA is also used to boost the concrete's ability to self-heal. Because the usual 2-4mm aggregate was replaced with a light weight aggregate of the same size comparable to a healing agent content of 15 kg m-3 concrete, this adjustment will affect the concrete's compressive strength. The ability of concrete with a LWA encapsulated healing agent to fix cracks was greatly enhanced

CONCLUSIONS AND FUTURE SCOPE OF RESEARCH

- Introducing bacteria to concrete is beneficial because it improves the properties of the concrete, making it superior to ordinary concrete.
- Bacteria reassemble the crystal by obstructing and correcting defects.
- Many studies have looked into the self-healing properties of concrete and determined that bacteria may increase the strength of conventional concrete by 13.75 percent in three days, 14.28 percent in seven days, and 18.35 percent in 28 days.
- Calcium carbonate crystal formation reduces water permeability by reducing fracture widths from 0.5mm to 0.35mm, lowering water permeability.

- After three days, compression strength increased by 30.76 percent, 46.15 percent after seven days, and 32.21 percent after 28 days.
- In a mathematical modal, it was observed that for high strength concrete classes, bacterial concrete had superior stress and strain values than controlled concrete.
- According to De Muynck et al. [3,] regular inspection will be less essential due to the use of self-healing material in the concrete.
- In a publication, Wiktor and Jonker et al. [2] calculated the crack-healing capacity of concrete using a light-weight aggregate encapsulating self-healing agent. They discovered that the crack width in bacteria-based specimens was less than 0.46mm. In capillary water suction tests, the relative capillary index of bacterial concrete was found to be lower than that of ureolytic mixed culture, and in gas permeability testing, the permeability of bacterial concrete was shown to be lower than that of conventional concrete.
- Three different materials are employed to discuss self-healing techniques in this study. To precipitate calcite in concrete fractures, bacteria are used in the initial application. This method can be used to patch large cracks in reinforced concrete. By filling the fracture, the technique does not improve the structure's strength, but it does restrict the passage to the reinforcement. As a result, liquids and ions that cause reinforcement corrosion are prevented, and the structure's endurance is increased. Water retention structures can also benefit from this technology. This procedure can be used to seal leaks and repair cracks. In particular, where it is difficult or impossible to maintain underground infrastructure.
- In the second application, SHCC (strain hardening cementitious composites) materials are investigated, which have a high potential for self-healing due to their low crack widths. www.selfhealingconcrete.blogspot.com has many self-healing concrete methods. New additions, such as microfibers SAPS (Super absorbent polymers), have even aided self-healing.
- Encapsulated oil and micro-steel fibres are employed to boost the self-healing capacity of asphalt concrete in the third application. The latter technique has been proven to work in the lab and is now being used on a live road in the Netherlands. More information regarding this topic can be found at selfhealingasphalt.blogspot.com.

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